PENNSTATE ARL

Institute for Manufacturing and Sustainment Technologies

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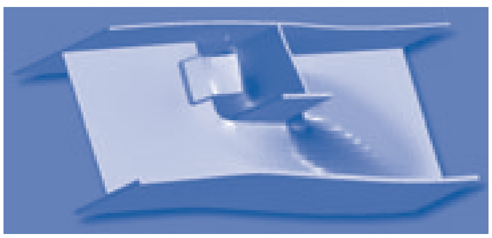
iMAST QUARTERLY

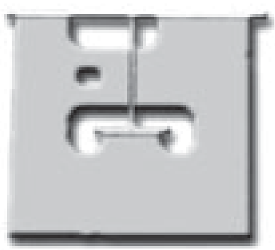
2003 No.4

Collarless Construction Techniques

For the past two years, iMAST has been working on collarless construction techniques to be used in conjunction with U.S. Navy ship construction. Current hull fabrication and naval shipbuilding practices that accommodate structural shape penetrations require the use of collars that allow stiffeners to penetrate transverse members while at the same time transferring loads. This practice is used at bulkhead and deck stiffener intersections. This technique requires a clearance to be made in the form of a square, just larger than the structural member. This clearance allows the bulkhead edge to become flush with the deck for welding. However, the clearance also results in a gap of several inches between the web face of the "T" and the clearance cut. As a consequence, a collar must be welded in order to restore structural integrity



The current state-of-the-art practice is quite labor-intensive because it requires extensive fitting and welding. The added heat from welding also causes increased distortion and fatigue within the structure. Resultant costs are high due to increased material handling requirements, piece/part fabrication and tracking, as well as coating challenges. Financial considerations today require that naval shipbuilders re-evaluate all segments of their production process. By employing new techniques such as optimized collarless construction, iMAST has determined that significant returns on investment can be achieved.



Based on the potential of the process development techniques addressed above, iMAST, in conjunction with the Navy Joining Center, Bath Iron Works, and Northrop Grumman Ship Systems, is developing techniques for reducing manufacturing cost associated with collars, while fostering greater accuracy in ship construction and reducing weight of ship structures. Methods currently under development and testing include several innovative designs that may be relatively easy to achieve in today's shipyard environment. Examples of these designs that are currently under investigation include fixed and bendable tabs that offer stiffener alignment and reduced parts and welding, as well as the complete elimination of collars and the use of bulb flats.

The overall objective of this program is to benchmark production costs. This will include addressing fabrication, handling and installation, fleet corrosion rates, weight, and structural penetration integrity (e.g. residual and concentrated stresses). Structural performance metrics, corrosion resistance, and alternative design assessment will also take place. Large-scale testing and analysis will determine selection criteria for identifying the most viable solutions.

Several designs (as depicted) have been identified through finite element analysis for testing. Large-scale testing employing hydrostatic and longitudinal compression loading is being formulated. The results of these tests will be used to select the most viable designs for further structural analysis and testing.

For more information about this program effort, contact the project leader, Rich Martukanitz, at (814) 863-7282, or by e-mail at <rxm44@psu.edu>. You may also contact the iMAST program manager, Bob Cook, at (814) 863-3880, or by e-mail at <rbc5@psu.edu>.

Focus On Manufacturing Systems

Report Documentation Page

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IN THIS QUARTERLY

DIRECTOR'S CORNER

Navy Management Change

I welcome our new ONR program managers. Mr. John Carney will supervise the operations of iMAST. Mr. Greg Woods will supervise the RepTech program. Mr. Carney has been associated with ONR's industrial programs office, managing the National Shipbuilding Research Program, the Center for Shipbuilding Technology, and the Gulf Coast Regional Maritime Technology Center. We have worked with Mr. Carney on numerous occasions and he is very familiar with our capabilities. Mr. Carney is heading up the strategic thrust concerning the next generation aircraft carrier. As iMAST is principally focused on carrier programs in FY04, the teaming with Mr. Carney is most appropriate.

Mr. Woods works for the Naval Sea Systems Command. He has a strong background in ship systems. We have worked with Mr. Woods over the years and, again, have a comfortable relationship with him. He is also very familiar with our capabilities. I expect our dealings with the RepTech points of contact to continue to promote valuable projects to the Navy and Marine Corps.

Because of their familiarity with our center, I expect our productivity to continue unheeded with the changeover from James Mattern to John Carney and Greg Woods. I appreciate what Mr. Mattern did for the Navy, and also for our institute. I expect to continue working with Mr. Mattern as he moves onto the LHA(R) program at NAVSEA.

This newsletter feature article discusses our technology in the Manufacturing Systems area. Dr. Mark Traband worked with Electric Boat Division in planning and designing a new facility at Quonset Point. The Metals Sub-Panel of the Joint Defense Manufacturing Technology Panel (JDMTP) nominated this project for special recognition.

As this newsletter goes to print, we will have just completed attending and participating in Defense Manufacturing Conference 2003. I'm anticipating that this year's conference will have afforded an excellent opportunity to talk to customers, manufacturers and resource sponsors. Hopefully, you were able to come by our booth and learn what we are developing at the Applied Research Laboratory. I encourage you to investigate our capabilities using our web site or the points of contact in our masthead.

As we approach a New Year, I want to thank you all for your continued support of our Navy Manufacturing Technology Program at ARL Penn State. I wish you a happy and safe holiday season. As 2004 approaches, I hope you will put visiting us and our facilities down as one of your New Year's resolutions, especially if you have not been here before.

Bob Cook

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FEATURE ARTICLE

Focus on Manufacturing Systems

Shipbuilding Facility Planning and Design: A Product-Centric Approach

by Mark Traband

Introduction

Electric Boat Corporation (EB) has a long-term vision for improving the fabrication of major submarine sections at its Quonset Point, RI, facility. This vision includes not only the investment in the new buildings and facilities, but includes a commitment to the up front planning required to incorporate process improvements and define future operational details. A new plate and shape processing facility that has recently been commissioned at Quonset Point is evidence to the time and effort given to planning. This new facility contains state-of-the-art machines in combination with process technology and innovation that dramatically reduces the internal cycle time, man-hours, and production support costs. In addition, kits from this new facility are now batched and delivered Just-in-Time to the Structural Fabrication operations.

The initial success of the plate and shape processing facility has prompted EB to invest in the improvement of down-stream production operations. The next process area being considered for modernization is structural fabrication. In structural fabrication, major sub-assemblies are built prior to insertion into a section of the submarine. The existing structural fabrication building, an old air refit facility dating to World War II, is severely under-facilitized for space and heavy lifting capacity to support the construction of modern submarine assemblies.

To support this new facility planning effort, a team of researchers sponsored by the Office of Naval Research has joined with managers, engineers, and trades personnel at EB. The goal of the effort is twofold: first, to define improved processes for assembling structural product families, and second, to use this process information to drive the design of the new facility.

Background

During the structural fabrication process, kits of prepared plates, shapes, and piping details are assembled into major structural components or products. Once a product is completed it is moved to another facility for installation into a submarine hull section. The products vary in size, shape, weight, material, work content, and resource requirements. Direct labor applied to these products can total over ten thousand manhours, with product makespans of several months. Examples of products include bulkheads, foundation tanks, pressure vessels, and decks. While production volumes for individual products are low, nominally one per year, several similar products will be made during that period.

Operations in the structural fabrication area include traditional processes such as shipfitting, welding, and pipe installation. However, the operation significantly differs from traditional surface ship fabrication in many ways. In particular, there is a very high proportion of multi-pass, full penetration welds, there is little commonality among piece parts, and radiographic inspection requirements are routine. The structural fabrication operation can be classified as a low volume, high mix, and high value-added process.

Currently at Quonset Point, structural products, and smaller subassemblies that feed these products, are assembled in various places around the shop. This requires these large components to be moved around the facility with some frequency. This material movement is very costly and does not add value to the product. Most of the resources in the structural fabrication facility are shared among several products. While shipfitters, welders, pipe fitters, machinists, inspectors and their equipment are applied to an individual assembly for some period of time, they are not fully dedicated to one product or class of related products. This results in different personnel working a product assembly for each hull. This limits the ability of EB to benefit from the experience acquired by trade personnel as they work on identical or similar products.

Also, support material and other resources such as welding supplies and inspection equipment are located in

PROFILE

Mark Traband is head of the Manufacturing Systems division at ARL Penn State within the Materials and Manufacturing department. In his role as a research associate, Dr. Traband conducts research in simulation and modeling of advanced manufacturing systems. Prior to joining ARL Penn State, Dr. Traband was an Office of Naval Research Fellow.

A native of Belair, Maryland, Dr. Traband earned a B.S. degree from Virginia Tech in industrial engineering and operations research. He completed his M.S. and Ph.D. degrees in industrial engineering at Penn State. You may contact Dr. Traband at (814) 865-3608 or by e-mail at <mtt1@psu.edu>.

centralized areas removed from the assembly workstations. This centralization of resources requires trades personnel to check out the needed equipment and move it to the worksite, then return it once work has completed. This contributes to non-value-added time.

Objective

Electric Boat is in the initial planning phase of a new structural fabrication facility. The goal of the new facility is to maximize efficiency and productivity. To accomplish this goal, non-value-added activities must be minimized. The non-value-added activities under scrutiny here include job setups, material movement, and locating resources. Creating a shopfloor layout and process build strategy that minimizes material movement and decentralizes support material, equipment, and trades personnel will minimize these non-value-added activities.

The overall objective of this effort is to maximize the efficiency of the new structural fabrication facility. This will be accomplished in two steps. First, a structured process modeling methodology is to be implemented on a product-by-product basis. This will serve to both document the existing structural fabrication process and identify resources and time required, and to serve as a process improvement forum prior to investing in the new facility. Second, the detailed requirements from the process models will be used to define the resource requirements for the new facility. These requirements will enable the definition of a product-centric facility design.

Methodology

The design of the new facility is the focal point for the improvement of the structural fabrication operations at Quonset Point. The facility design depends heavily on the manufacturing concept to be used in the production of the major submarine structural assemblies. Since EB has elected to use a product-centric approach, production activities will be focused on families of major structural components. The facility design is based on these product families, in that each product family will be manufactured in a semi-self contained workcell. By creating several workcells, in which every resource needed to complete a product is located in and dedicated to the workcell, EB will have decentralized personnel and equipment, which will decrease the movement of resources and material.

In a product-centric approach, well-defined and semi-exclusive workcells are created to produce one product or product family. The workcell contains and is responsible for all of the resources, material, and personnel required for producing a product family. Therefore, a product family manager is then responsible for all aspects of manufacturing the product, from personnel (shipfitters, welders, and welding technicians) to equipment (welding and tack equipment, automated welding equipment, fixtures, grinders, and heaters). Other resources such as shop cranes, inspection resources, and outside machining would still be shared among the rest of the facility. This approach aims to minimize non-value-added time attributed to gaining control of shared resources and moving material from one location to another.

To develop a product-centric facility plan, the project team has pursued a methodology that focuses on two major tasks. The first task is to develop detailed process models of the major products. This will enable the design team to identify key resources required for the assembly of these products, as well as to define appropriate manhour requirements by trade and identify makespans for the products. Using the data defined in the first task, the second task is to define a facility plan. This will include the definition and analysis of alternative layouts to support the production, as well as the identification of resources requirements. More detail on these steps in the methodology is provided in the following sub-sections.

PROCESS MODELING

The product-centric structural fabrication approach depends heavily on the product families that make up the concept. A family must contain products that are similar enough in terms of resource and physical requirements to warrant them to be produced in the same area by the same set of resources. For example with submarines, the resources required to produce deck structures are very different than those required when fabricating sonar spheres. Products are sorted into different families based on several characteristics or attributes. For this effort, these attributes include:

- Average and maximum plate thickness
- Product weight
- Fitting to welding ratio
- Product shape and structure type
- Fixturing requirements
- Welding and preheat requirements
- Piping complexity
- Machining requirements
- Inspection requirements
- Pressure testing requirements

In addition to these product attributes, production requirements also had an effect on the product family definition. These requirements included the number of items produced in a given time period, the physical space needed for production, and production phasing. It is inevitable that some products in one family may have many of the attributes of products in another family, but still may be different enough to warrant being its own family. In these instances it is logical to locate similar workcells near one another to exploit their similarities. Approximately 100 products were identified by EB as candidates for assembly in the new structural fabrication facility. Analysis showed that over eighty percent of the workload would be made up by 30 of these products. For each of these products an analysis was performed based on the characteristics above. This resulted in the identification of the following seven product families:

- Spheres and flasks
- Foundation tanks
- Bulkheads
- Decks

- Large foundations and components
- Small foundations
- Tanks

This would result in the generation of seven workcells, each with specific requirements for physical space and proximity to shared resources.

In an effort to better understand and classify the products under consideration, detailed process models were developed for at least one representative product from each candidate product family. During this phase of the effort, key trades personnel from shipfitting, welding, pipefitting, and inspection provided invaluable insight into the fabrication process. The process models were developed in DelmiaTM Process Engineer and DPM for Assembly. To do this, CATIATM CAD models of the products were used as a starting point. These models were imported into Delmia, and the project team documented process assembly sequences based upon current structural assembly practices. The process modeling included annotating the assembly sequence with operations (i.e. fit, weld, inspect, move), and identifying resources required (i.e. crane, equipment, skills). The compilation of this sequence, task, and resource information comprises the detailed process map for the as-is product fabrication.

During this process modeling effort, the project team generated valuable suggestions for potential process improvement. To capture these improvements for implementation in the new facility, the Delmia process models were updated to reflect the improved or to-be process.

FACILITY PLANNING

In planning the new structural fabrication facility, several factors including location on site, physical size, interior layout, material handling, and access needed to be taken into consideration. The shop floor design must facilitate efficient production in terms of maximizing the utilization of space and minimizing material movement and other non-value-added operations. The overall facilities planning process as described by Tompkins et. al is:

1. Define the products to be manufactured.
2. Specify the manufacturing processes and related activities required to produce the products.
3. Determine the interrelationships among all activities.
4. Determine the space requirements for all activities.
5. Generate alternative facilities plans.
6. Evaluate the alternative facilities plans.
7. Select the preferred facilities plan.
8. Implement the facilities plan.
9. Maintain and adapt the facilities plan.
10. Update the products to be manufactured and redefine the objective of the facility.

In the previous section, Process Modeling, the details for items 1, 2 and 4 were specified. In this portion of the effort, the focus is on items 3 and 5 through 7.

Determining the interrelationships among all activities is a key component to the facility layout process. Product workcells that have common characteristics and processes will need to be located near one another to maximize the utilization of the resources used to create the products. To determine the interrelationships among all activities, the characteristics and processes of each product were evaluated in greater detail. It was observed that, as expected, products in the same family had the same characteristics; however, products from different families also shared properties and processes. This was significantly apparent in the characteristics and processes of the subassemblies. For instance, a major subassembly in one of the bulkheads shares most of the products, processes, characteristics and resources as a major subassembly on one of the decks. Therefore, it might be beneficial for these two workcells to be located in close proximity to one another.

Observing that many of the products shared small subassemblies that required the same resources and similar processes it was determined that another workcell should be incorporated. This workcell is in addition to work areas between the product workcells and is represented by the Small Foundation Workcell. The Small Foundation Workcell is used for small subassemblies that can be moved around the shop much easier than the large products. Larger subassemblies would still be produced either within the product workcell or between product workcells.

Workcells, like products, have characteristics and specific requirements. In fact, the characteristics of the workcells can be directly determined from the characteristics of the products. In addition to those characteristics, other workcell characteristics like size, scheduling, and resources were identified. The workcell and product characteristics were used to determine the interrelationships among the workcells. The project team identified several interrelationships between the workcells and was able to assign a closeness or proximity priority for each workcell. This priority gave a general idea of how the workcells should be organized, however, the size of each workcell must be considered to get a more detailed layout.

The size of the workcell is governed by many factors. These include: Product size, resource requirements, and product scheduling. The size of the workcell is determined by the size of the product along with the fixture and manufacturing resources. Scheduling or time phasing of construction plays large role in the size of the workcell. For instance, the foundation tank workcell produces 3 tank complexes, but only requires space for the largest complex because the span time for each complex is small enough that they can be produced to meet the schedule. However, the 2 decks in the Decks workcell have span times that require each deck to have space for production. Manufacturing resources, such as welding machines, heating equipment, and fixtures also factor into the size

required for each workcell.

Size (ft^2) requirements for each product in the current manufacturing environment were found and translated into preliminary 2-dimensional block CAD model. A 2-dimensional CAD model of the new facility was also generated and the block CAD workcells were inserted. This primitive model served as the preliminary facility layout and served as a discussion piece for questions concerning isleways, cranes, and other high level issues. From these discussions, several suggestions, and other requirements were brought to light and a more detailed facility layout was generated. A 3-dimensional model was created complete with cranes and isleways. Product models were also inserted into the workcells along with fixtures, tables, and other resources. This new model was again presented to the project team. Once again, more questions, suggestions, and requirements were generated. This iterative process was performed, each time adding more detail, until a suitable facility design was obtained.

Results

Within the scope of this effort, very detailed process models (down to the individual part assembly level) were created for two of the major components, a foundation tank and a bulkhead, and high-level process models were created for several other major components. This included the following structural assemblies:

- Foundation Tanks – 4
- Bulkheads – 1
- Spheres – 1
- Decks – 2

A foundation tank is provided in Figure 1 to give an example of the level of detail to which the process modeling was taken. This example has been greatly simplified for inclusion in this publication, omitting details of piping and structure.

As a result of the process modeling effort, several process improvements were realized. These

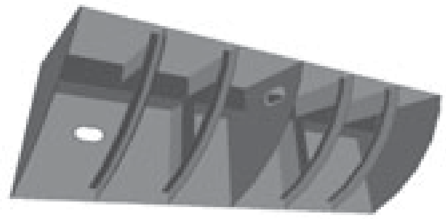

Figure 1. Example foundation tank.

improvements reduced non-value added time and overall production time for each component modeled. Non-value added time was reduced by eliminating or minimizing the time spent finding service material and temporary bracing. New process sequences and build strategies decreased the overall process time to complete these components. These changes resulted in greater tha 20% savings in manhours for fabricating each component.

During the facility layout process, several candidate designs were created. These designs ranged from very general to very detailed. An example of one of the designs considered is shown in Figure 2.

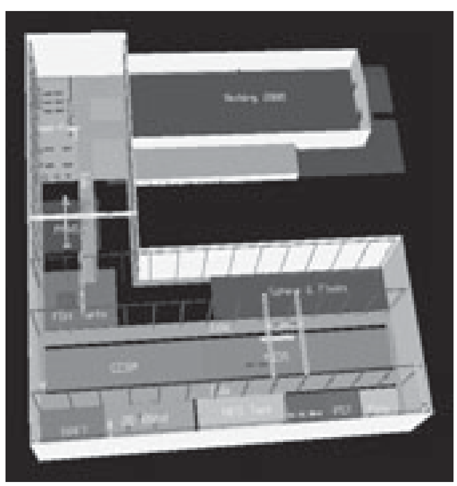

Figure 2. Facility layout concept.

This layout provides numerous advantages over the current production facility at Electric Boat. Under this concept, kitted material will flow from the Steel Processing facility (upper right in Figure 2) into a subassembly area that contains manual, mechanized, and fully automated cells. These subassemblies will then flow into the appropriate product cell for final structural fabrication. In the proposed facility products that share similar processing requirements and fabrication sequences are located in close proximity to each other. In addition, significant attention is being paid to the actual design of the product cells, including the location of electrical and gas services, power supplies, and part staging.

Conclusions

Simply building a new facility does not guarantee that the operations will be more efficient. In fact, the operations must be better in the new facility in order to justify the capital expenditure. The work detailed here shows one method used to design the operations of a new facility in order to minimize excessive, non-value-added time spent in material movement, job setup, and locating resources.

Understanding the products that are to be produced, and the processes used to produce them is the most important component of designing a new facility. Knowing the characteristics and build strategies of products allows designers to determine interrelationships among the products, which in turn generates simple layout designs. From these simple layout designs, more detailed designs can be created and improved until a final design is agreed upon.

The process modeling effort was very beneficial to the facility design in several ways. This effort not only documented the current process, but it also presented process improvements, documented those process improvements, allowed for more detailed work instructions, and gave valuable information for the facility design effort. The process models can also be translated into a discrete event simulation model, where the system can be analyzed in more detail.

References

Plant Layout and Design, Tompkins, J.A., White, J.A., Bozer, Y.A., Frazelle, E.H., Tanchoco, J.M.A., Trevino, J., 1996

Ed Liszka (left), director of the Applied Research Laboratory, and Bob Cook (right), director of ARL's iMAST Navy ManTech Program, pause for a photo with Congressman Jack Murtha, who visited iMAST's exhibit booth at ARMTech.

ARMTech Showcase

Members of iMAST recently participated in the annual Armstrong County Technology Showcase held in Kittanning, PA. Participation in events like this showcase is an essential part of the technology transition effort which Navy ManTech requires. As with any technology, the ability to transfer and implement that technology depends on finding appropriate industry partners. Events like Armstrong County (western Pennsylvania) Technology Showcase provide an opportunity for government, academia, and industry to meet in order to identify and exchange new ideas for technogical innovation. This, in turn, provides a vehicle which can enhance the production and performance of DoD-related systems, at an affordable cost to the U.S. taxpayer.

ONR Naval-Industry R&D Conference

The Ronald Reagan Building and International Trade Center in downtown Washington, D.C., once again provided an impressive setting for iMAST to display its program effort. Sponsored by the Office of Naval Research, the conference has been established to leverage dialog between government, industry, academia, and the U.S. Navy and Marine Corps. A series of interactive breakout sessions provided forums to seriously discuss the challenges facing the defense industrial base. Next year's annual conference will be held again in Washington, D.C. at a date to be announced. Keep checking our calendar of events for more information.

John Williams briefs SBIR/STTR audience at recent ARL Penn State-sponsored seminar. Approximately 80 visitors participated in the seminar which included a panel discussion featuring previous awardees. A tour of ARL facilities was also conducted.

ARL Hosts SBIR/STTR Seminar

ARL Penn State recently hosted its third U.S. Navy Small Business Innovation Research (SBIR) and Small Business Technology Transfer (SBTTR) seminar in State College, as part of its industrial outreach effort. The Navy SBIR/STTR programs provide over two billion dollars directly to small high-tech firms to address the R&D needs of government agencies. The U.S. Government realizes that small business provides much of the innovation required to keep this country on the leading edge. Grant money provided by the programs supports early stage R&D efforts that match government agency areas of interest. Since it began hosting these seminars, STTR grants have increased from zero the first year to 25 overall. Of the 25 awards generated, Penn State has partnered in eight. Penn State leads the U.S. in research institutes supporting STTRs. If you would like to find out more information about Penn State's resources and effort, contact ARL's Tom Hite. Tom can be reached at <tmh9@psu.edu> or by phone at (814) 777-0789. John Williams, the Navy SBIR/STTR deputy program manager can be reached at <williajr@onr.navy.mil> or by phone at (703) 696-0342.

New Navy Program Manager

Mr. John Carney has been designated as iMAST's new program manager for the Navy ManTech Program effort ongoing at ARL Penn State. Mr. Carney succeeds Mr. Jamie Mattern who has been given additional responsibilities within the Naval Sea Systems Command. As program manager, Mr. Carney will provide financial and programmatic oversight to iMAST, as directed by the Office of Naval Research. An industrial engineer, Mr. Carney holds B.S. and M.S. degrees from Virginia Tech. A native of Sterling, Virginia, Mr. Carney's technical interests include shipbuilding technology.

Mr. Carney can be contacted by calling (703) 696-0352, or by e-mail at <carneyj@onr.navy.mil>. We are pleased to have Mr. Carney as part of the ARL Penn State-Navy ManTech team.

CALENDAR OF EVENTS

1–4 Dec.	Defense Manufacturing Conference 2003	*visit the iMAST booth*	Washington, D.C.
2004			
Jan. TBA	ShipTech 2004	*visit the iMAST exhibit table*	TBA
1–3 Feb.	Tactical Wheeled Vehicle Conference		Monterey, CA
3–5 Feb.	U.S. Naval Institute West 2004 Technology Expo		San Diego, CA
15–18 Mar.	NDIA Joint Undersea Warfare Technology Spring Conference		Monterey, CA
6–8 Apr.	Navy League Expo	*visit the iMAST booth*	Washington, D.C.
May TBA	U.S. Coast Guard Innovation Expo		Baltimore, MD
1–4 May	20th Annual National Logistics Conference		Sparks, NV
3–4 May	2004 Navy Opportunity Forum		Reston, VA
Jun. TBA	Johnstown Showcase for Commerce	*visit the iMAST booth*	Johnstown, PA
8–10 Jun.	American Helicopter Society Forum 60	*visit the iMAST booth*	Baltimore, MD
Aug. TBA	ONR R&D Conference	*visit the iMAST booth*	Washington, D.C.
2–6 Aug.	TechTrends 2004	*visit the iMAST booth*	Pittsburgh, PA
18–20 Aug.	ARMTech	*visit the iMAST booth*	Kittanning, PA
Sep. TBA	Marine Corps League Expo	*visit the iMAST booth*	Quantico, VA
Sep. TBA	Marine Corps Systems Command Industry Day		Crystal City, VA
Oct. TBA	Expeditionary Warfare Conference		Panama City, FL
Oct. TBA	AUSA Expo		Washington, D.C.
Oct. TBA	DoD Maintenance Conference		TBA

Quotable

"We build the best ships in the world, but we build them with technology that is lagging the rest of the industrialized world."
—Philip Dur, President, Northrop Grumman Ship Systems

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